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AID Report 61-99 7 July 1961

SOVIET LITERATURE ON PROTECTIVE STRUCTURES
AND COMPONENTS

AID Work Assignment No. 13
Report 2

Science and Technology Section
Air Information Division

AID Report 61-99 7 July 1961

SOVIET LITERATURE ON PROTECTIVE STRUCTURES AND COMPONENTS

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Report 2

Science and Technology Section
Air Information Division

SUBJECT: Monthly Report - AID Work Assignment No. 13

PERIOD : To May 31 1961

This is the second of a series of reports reviewing Soviet developments in the construction of protective structures and components of automatic weapons systems. This report is based on materials received at the Air Information Division prior to 31 May 1961. It deals with the following topics:

I. Preparatory work

II. Construction methods

IV. Communications

SUBJECT: Monthly Report - AID Work Assignment No. 13

PERIOD : To 31 May 1961

TOPIC I. PREPARATORY WORK

1) Arkhangel'skiy, M. M., D. I. Dzhincharadze, and A. S. Kuris'ko. Raschet tonnel'nykh obdelok (Design of tunnel linings). Moskva, Transzheldorizdat, 1960. 344 p.

Experimental Determination of Rock Pressure in Underground Areas (pp. 38-44)

Experimental determination of rock pressure is of great scientific interest in undergound construction, particularly in that it permits a check of the validity of theoretical aspects and the determination of some empirical coefficients required in strength calculations. The authors of this work place methods of determining rock pressure into the following three groups: 1) direct measuring of the pressure in a given area by means of columnar dynamometers, 2) indirect methods, involving the measurement of deformations (and hence stresses) in supporting structures or liners and the calculation of rock pressure from the values obtained, and 3) direct measuring of rock pressure at various points by special instruments, usually of the diaphragm type, called "geotechnical gages."

One of the simplest columnar dynamometers used for direct measurement is the one designed by Academician A. N. Dinnik (Fig. 1). The dynamometric column consists of metal tube 1 with two metal blades 2 welded to the tubing. The reduction of tubing length l under pressure is measured by means of deflection f of the metal blades.

The columnar dynamometer designed by Engineer D. D. Golovachev consists of a hollow cylinder with a taut string passing through its axis. An actuating electromagnet is placed near the string, and the wires of the magnet are brought out through the pipe at the bottom of the dynamometer. This dynamometer is based on the "string method" of Professor N. N. Davidenkov. [In this method stress is calculated from deformation, which is determined from the "tune" (number of vibrations) of a string in stressed (loaded) and unstressed (unloaded) conditions.] Dynamometer a (Fig. 2) is placed on a supporting pillar and pressed against steel plate b situated on a ground tie. With an outer diameter of 80 mm and an inner diameter of 75 mm the dynamometer is intended for 5-ton pressure but can be used with a double overload (i.e., 10 tons).

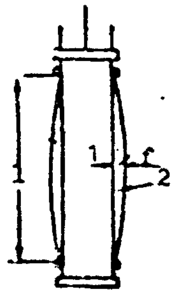


Fig. 1.

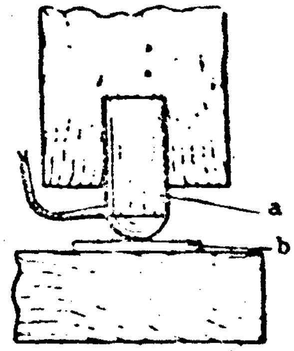


Fig. 2.

With the indirect method, wire strain gages are the most accurate means of measuring deformations. In 1949 the All-Union Scientific Research Institute of Mine Surveying made use of a columnar dynamometer equipped with wire strain gages, which measure deformations of the dynamometer walls. Basically, this device (Fig. 3) consists of a ДСД-30 dynamometer and a measuring station. The ДСД-30 is made up of measuring shell 1 with wire strain gages 2 cemented to the interior walls. The constantan strain-sensitive wire for the gages is 0.05 mm in diameter. The shell is enclosed by two covers, 3 and 4, and set on base 5 with ball support 6. The base and the top cover are held together by three springs 7. Pin 8, pressed into the hole of the top cover, serves for centering the dynamometer on the supporting pillar. Two cables are passed through holes in the shell wall and connected with the cables of the measuring station.

Under the effect of top pressure the measuring shell and consequently the wire gages undergo deformation, which changes the wire resistance. The change of resistance is measured, and the pressure sustained by the shell and the pillar can be determined. Columnar dynamometers are very convenient because of the manner in which they are placed directly under the supporting pillars so as not to interfere with the tunneling work.

For measuring deformations and bending stresses of upper wooden beams Davidenkov's "string method" can be used successfully. With this method screws are secured to the upper beam (1, Fig. [illegible]) of the frame being tested. Thin steel strings are then stretched taut between the screws. The "tune" (number of vibrations) of the strings is measured, and the beam is unloaded by raising neighboring beams 2 with screw jacks 3. After the beam has been unloaded, the number of string vibrations is measured once again. The difference between the

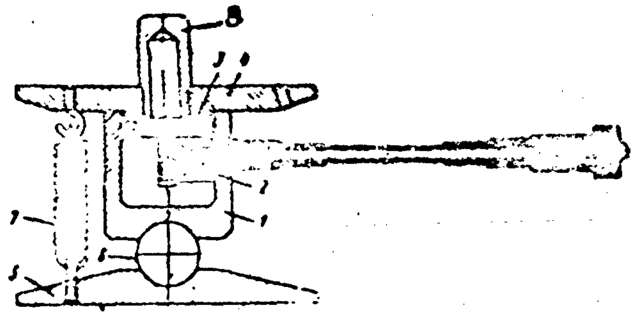


Fig. 3.

number of vibrations for each measurement determines the change in string length and therefore the change in wood-fiber length between the screws and the intensity of the load.

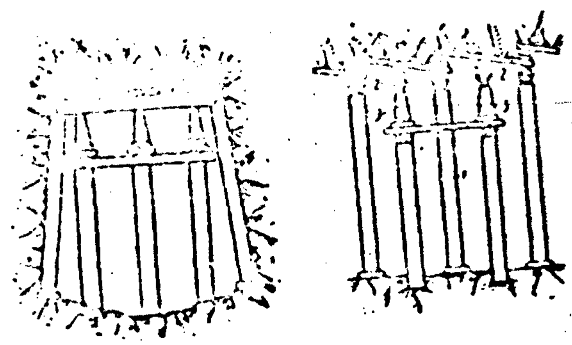


Fig. 4.

Davidenkov's method can be used to measure deformations in a variety of structures. In tunneling it is used only for upper wooden beams. For measuring stresses in metal supports and cast-iron liners the bonded wire strain gages are more advantageous.

The direct measuring of rock pressure at various points is accomplished with "geotechnical gages." These gages usually consist of a metal sleeve with a thin steel diaphragm which deflects under the rock pressure. Since the magnitude of deflection is very small, high-accuracy instruments must be used. Preliminary to measuring operations these instruments are calibrated under static pressure, and a graph is plotted for each instrument.

The All-Union Scientific Research Institute of Highway Construction successfully uses string gages and gages employing inductance transducers. Fig. 5 illustrates a string gage where diaphragm M of the cylindrical steel housing is subjected to rock pressure p. By means of switch S electromagnet E is energized by a current pulse which causes vibration of string C. String vibration in the magnetic field induces an electromotive force in the winding. The current frequency, and string vibration frequency, is determined by comparison with the frequency of test generator G. When diaphragm M deflects under rock pressure p posts K turn at a certain angle and increase the tightness of string C, which is stretched between the posts. The vibration frequency of C is thus increased. Rock pressure p is then determined by means of a calibration curve plotted for frequency as a function of pressure.

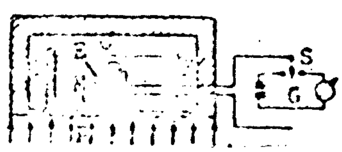


Fig. 5

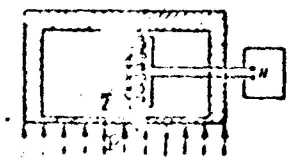


Fig. 6

The schematic diagram of a "geotechnical gage" employing an inductance transducer is shown in Fig. 6. With the deflection of the diaphragm, gap Z decreases, changing the inductance of the winding. The rock pressure is determined from the calibration curve plotted for inductance as a function of pressure.

"Geotechnical gages" are placed in position for long periods of time and as a rule cannot be reached after construction is completed. Since their reliability must be very high, they are hermetically sealed to prevent penetration of water or water vapor.

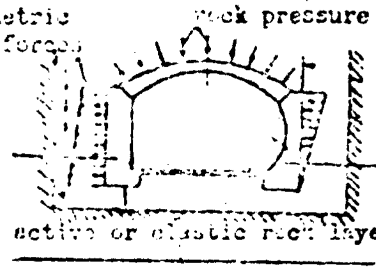
The Division of Tunnels and Subways of the All-Union Scientific Research Institute of Railway Design and Construction has conducted a series of experiments in direct measuring of rock pressure in tunnels by means of string gages. For reliable contact of the gages with the earth, sand is forced behind the tunnel liners. The result of measurements with the string gages, as well as those made with wire strain gages, were considered satisfactory.

Davydov Computation Method for Monolithic Tunnel Linings (pp. 49-117)

The computation method in the design of monolithic tunnel linings developed by Professor S. S. Davydov has found use in the design of railway and highway tunnels and special-purpose underground structures. Davydov considers that the arch of a tunnel lining is subjected to rock pressure and the side walls, to volumetric forces and elastic resistance. Around the lining an elastic layer of rock forms which works together with the lining (Fig. 7). The thickness of the elastic layer is determined from this equation:

$$\max \sigma = 1.2 \sigma_{init.} \tag{1}$$

where max σ is maximum rock pressure along the side surface of the wall after construction of the lining, and $\sigma_{init.}$ is the original rock pressure before the lining was installed.



The thickness of the elastic layer at the base of the structure can be determined by N. A. Tsytovich's formula:

$$H_b = \frac{(1-\mu_0)^2}{1-2\mu_0} \omega d_\phi \tag{2}$$

where μ_0 is the coefficient of transverse expansion, d_ϕ is the width of the wall base, and ω is a coefficient depending on the ratio of the length of the underground area L to d_ϕ.

By designating

$$\Omega = \frac{(1-\mu_0)^2}{1-2\mu_0} \omega$$

this equation is obtained:

$$H_b = \Omega d_\phi \tag{3}$$

For values of L/d_0 from 1 to 10 and higher, the values of Ω vary within the following limits. for $\mu_0 = 0.2$, from 0.9? to 2.26; for $\mu_0 = 0.3$, from 1.08 to 2.60; and for $\mu_0 = 0.4$, from 1.58 to 3.82.

The elastic characteristics of the rock are functions of generalized modulus of longitudinal deformation E_0 and coefficient of transverse deformation μ_0. For sand or clay the generalized modulus of longitudinal deformation E_0 in kg/cm^2 can be determined by Gersevanov's formula:

$$E_0 = \frac{(1-\xi)(1+2\xi)}{1+\xi} \cdot \frac{1+A}{a} \qquad (4)$$

where ξ is the coefficient of side pressure; a is the coefficient of density increase with the increase of pressure as determined from the compression curve; and A is the length of a section of the vertical axis of the compression curve $A = \varepsilon_1 + ap_1 = \varepsilon_2 + ap_2$ in which ε_1 and ε_2 are coefficients of rock porosity at pressures p_1 and p_2.

The generalized modulus of longitudinal deformation can also be determined from compression-test data by this equation:

$$E_0 = \alpha \cdot p/S \cdot \sqrt{F} \qquad (5)$$

where F is the die-impression area (cm^2), p is the rock pressure (kg/cm^2), S is contraction (cm), and α is a coefficient which equals 0.823 for sand, 0.761 to 0.747 for argillaceous soil, and 0.735 to 0.722 for clay.

The value of the coefficient of transverse deformation is determined by this equation:

$$\mu_0 = \frac{\xi}{1+\xi} \qquad (6)$$

The values of E_0 and μ_0 in the first approximation can be taken from tables [presented in the book]. The tables provide sufficient accuracy for preliminary design calculations.

According to Davydov, the design of the tunnel lining begins with the selection of dimensions for the tunnel. [The tunnel shapes and dimensions for various types of rock — six tunnel shapes — are given in tabular form.] The thickness of the lining in the various cross sections is determined from the value of the rock-strength coefficient and the dimensions of the tunnel cross section. The rigidity of the lining wall is determined by the following equation:

$$\alpha = \frac{\pi E_0}{6E_1} \cdot \frac{1-\mu^2}{1-\mu_1^2} C^3 \qquad (7)$$

Values E_o and μ_o are compiled from tables [presented in the book]. Term EI is equal to $E \cdot bd^3 c\mu / 12$, and μ is the coefficient of transverse deformation of concrete, usually 1/5 to 1/6. Term C = 0.2 h_y, where h_y is the height of the lining wall.

The dimensions of the tunnel cross section in daylight must satisfy this equation:

$$l_c \leqslant 8 \cdot \sqrt{\frac{f_c \, f_{kp}}{l_c}} \qquad (8)$$

where l_c and f_c are daylight dimensions (Table 1) and f_{kp} is the rock strength coefficient.

If this equation is satisfied, the horizontal components of volumetric forces acting against the wall fully neutralize the horizontal component of the arch pressure. In this case the arch is calculated without consideration of abutment displacement. If the equation is not satisfied, the horizontal components of volumetric forces cannot neutralize the forces from the arch applied at the top of the wall, and the wall will move outward exerting pressure on the rock. In this case the arch is considered as a system resting on elastically displacing abutments.

When $\alpha \leqslant 0.05$ and equation (8) is not satisfied, there are a rigid wall and a general case of calculation. When $\alpha \leqslant 0.05$ and equation (8) is satisfied, there are a rigid wall and a particular case of calculation (See: Davydov, S. S. Raschet i proyektirovaniye podzemnykh konstruktsiy [Design and Calculation of Underground Structures]. [Moskva], Stroyizdat, 1950). When $\alpha > 0.10$ and equation (8) is not satisfied there are an elastic wall and a general case of calculation. When $\alpha > 0.10$ and equation (8) is satisfied, there are an elastic wall and a particular case of calculation. When $\alpha > 0.05$ and < 0.10 the wall can be considered either rigid or elastic.

At present the design of tunnel linings is carried out in two stages. In the first stage the main dimensions of the lining are determined on the basis of past experience. In the second stage the actual working design is prepared in which all dimensions of the lining are determined on the basis of strength calculations. However, even after the second stage has been completed, the design can be modified slightly to conform to specific geological conditions discovered during tunneling.

The Davydov method is illustrated by two sample calculations. The first requires the design of a concrete tunnel lining with a rigid wall under conditions of mobility of the

arch abutments (Fig. 8). The following parameters are given: l_c = 4.50 m; h_y = 3.00 m; depth of the tunnel underground H = 6.5 m; incompetent rock with a strength coefficient of 0.6; angle of internal friction, φ =30°; modulus of longitudinal deformation E_0 = 2000 ton/m^2; coefficient of transverse deformation μ_0 = 0.3; specific weight γ = 1.5 ton/m^3.

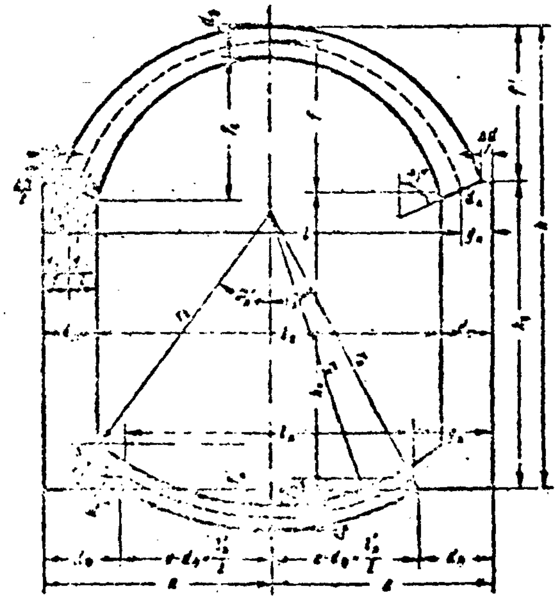


Fig. 8.

After the second stage of design and strength calculations in the various cross sections other changes were made. The final shape of the lining cross section is shown in Fig. 9. All dimensions are given in centimeters.

In the second example the linings of a two-way straight railway tunnel are designed for medium-strength rock. Fig. 10 shows the cross section of the tunnel with all the dimensions in centimeters. Seven other one-way railway tunnels for various types of rock are also illustrated in this section of the book.

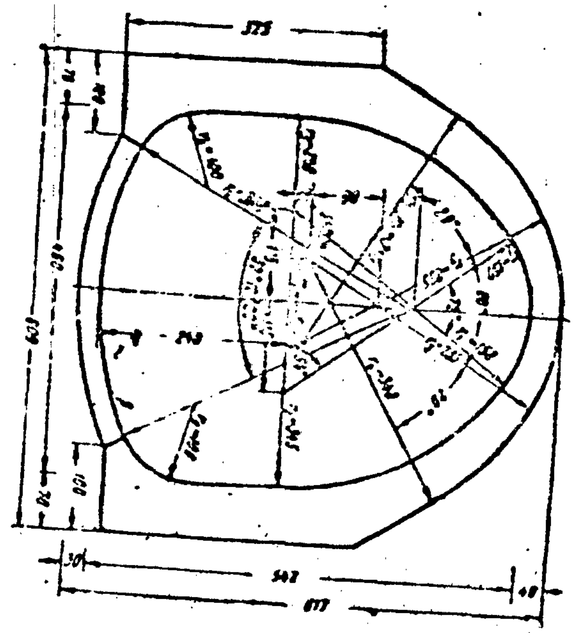


Fig. 9.

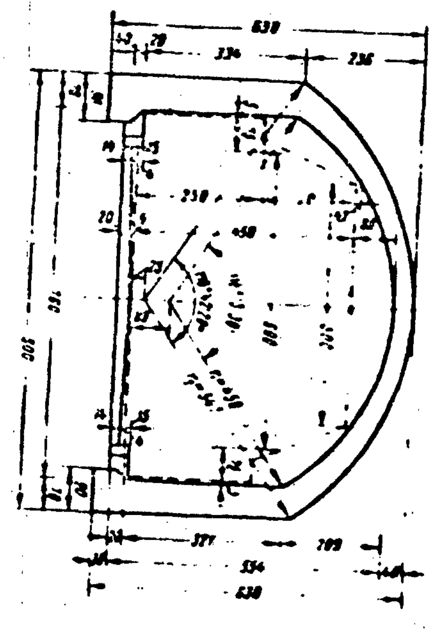


Fig. 10.

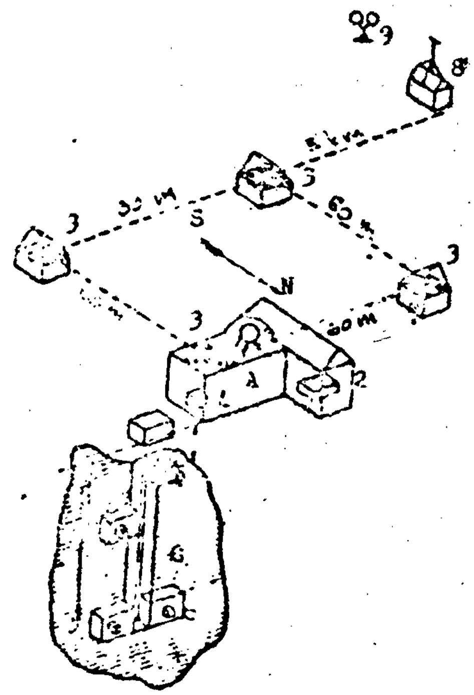
2) Musi[illegible], A. Ch. New mechanisms and instruments in mining worl[illegible]. IN: Akademiya nauk SSSR. Vestnik, no. 2, Feb 196[illegible], 48-53. AS262.A627 1961

The Laboratory of Rock Pressure of the Institute of Mining, Kazakh Academy of Sciences, has developed the [illegible]C-3 microseismic device for determining stress intensity in rocks over excavated areas. Intensity is determined by listening and recording of noise pulses (scratches) whose frequencies increase with increasing stress intensity. The device consists of the following: a Rochelle salt piezoelectric detector, which is placed in a crack or a drilled hole during the operation; a three-stage audioamplifier with gain up to 50,000; a headset; and a dry battery for power supply.

For each set of local conditions a "noise scale" (in pulses per minute) is determined pursuant to stress intensities. For example, at the [illegible] mine, which has a sandstone roof, the device signalling the approaching intensification of stress intensity was instrumental in predicting a collapse of the roof. In this case 3-5 pulses per minute corresponded to deformation without visible breakdown; at 7-11 pulses per minute spalling was observed; at 35-45 pulses per minute the roof collapsed.

The Institute has also developed a method for observing the movement of rock over excavated areas. Bullets loaded with radioactive cobalt 60 are shot horizontally into a drill well to given depths. With the [illegible] type gamma-sensitive device and a semiautomatic depth-measuring device the displacement of the rock can be determined by periodical measuring of the position of the bullets.

3) Layout of apparatus for recording cosmic rays at the Laboratory of Physical Problems of the Yakutskiy Branch, Siberian Division, Academy of Sciences USSR (Ф = 51.0°, Λ = 193.8°). IN: Akademiya nauk SSSR. Yakutskiy filial. Variatsii intensivnosti kosmicheskikh luchey (Intensity variations of cosmic rays). Moskva, 1960. (ITS: Trudy. Seriya fizicheskaya, no. 3) 166.



Layout of apparatus for measuring cosmic rays

A - main building of the laboratory; B - equipment for measuring atmospheric showers; C - underground portion of the laboratory [equipment at 7-, 20-, 60-m water equivalent depth]. 1 - ACK-1 ionization chamber; 2 - neutron monitor; 3 - atmospheric shower-measuring equipment [consisting of three separate trains with 30 Geiger-Müller counters each]; 4 - counter train; 5 - threefold coincidence counter train; 6 - counter train; 7 - C-2 ionization chamber; 8 - uhf radio-receiver station; 9 - stratospheric radiosonde counter.

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PERIOD : To 31 May 1961

TOPIC II. CONSTRUCTION METHODS, MATERIALS, AND EQUIPMENT

1) Silakov, A. Explorer device. Ekonomicheskaya gazeta, 6 May 1961, 4.

A camera for photographing in color and televising interior surfaces of borehole walls has been developed at the Department of Electrical Engineering, Institute of Communications imeni Bonch-Bruyevich, under the direction of the Department chairman, Professor P. V. Shmakov. The entire device is contained within a special nonmagnetic steel tube 60 mm in diameter and 1690 mm long. The camera has two film spools and is lowered into the borehole on a cable. Focusing of the camera, exposure time, and the switchover from still photography to television are controlled from a panel above ground.

2) First to appear in worldwide use. Ekonomicheskaya gazeta, 4 May 1961, 2.

The Zhdanov Heavy-Machinery Plant has begun the manufacture of the MB-5 shaft-sinking machine for sinking shafts 5 m in diameter to depths of 500-600 m. The machine can drill in both soft and very hard rock and bores at a rate of 120-150 m per month. Eight operators are required to run the machine, and it is controlled from above ground.

3) Television camera on the end of a drill. Yunyy tekhnik, no. 2, Feb 1961, 21.

Czechoslovakian engineer M. Krajčík has designed a television unit for visual observation of borehole interiors. The unit is a specially designed cylindrical television camera which is fastened to the drill rod and lowered into the borehole. It transmits the image of the borehole interior to a screen above ground. At present the working range of the unit is 250 m. However, with some improvements the range can be extended to 1500 m.

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TOPIC IV. COMMUNICATIONS

1) Il'in, A. A. System of overall remote control of mining work. IN: Akademiya nauk SSSR. Sibirskoye otdeleniye. Izvestiya, no. 2, 1961, 11-16.

After an investigation of the operations of dispatcher supervisory control systems ([illegible]-4, ДТС-1, etc.) for the mining industry, the Mining Institute of the Siberian Division of the Soviet Academy of Sciences reveals that none of the existing systems of communication can either meet the desired requirements or serve as starting points in the design of new systems. The Institute makes the following recommendations for a new general-purpose system:

1) Existing power cables should be used as communications links, since *radio channels and other communications links in mines operate unsatisfactorily.*

2) A frequency-type coding in the 20-3000 c range should be used for reasons of greater simplicity, reliability, and noiseproof characteristics.

3) Operating frequency should be maintained in the 10-100 kc range.

4) A unit-type system is more feasible by virtue of its greater flexibility.

5) Semiconductors and contactless devices should be used to insure reliability.

6) Computers should be employed for processing input information.

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2. Il'in, A. A. System of overall remote control of mining work. IN: Akademiya nauk SSSR. Sibirskoye otdeleniye. Izvestiya, no. 2, 1961, 11-16.

3. Musin, A. Ch. New mechanisms and instruments in mining work. IN: Akademiya nauk SSSR. Vestnik, no. 2, Feb 1961, 48-53. A3262.A627 1961

4. Silakov, A. Explorer device. Ekonomicheskaya gazeta, 6 May 1961, 4.

5. Arrangement of apparatus for recording cosmic rays at the Laboratory of Physical Problems of the Yakutskiy Branch, Siberian Division, Academy of Sciences USSR (Φ = 51.0°, Λ = 193.8°). IN: Akademiya nauk SSSR. Yakutskiy filial. Variatsii intensivnosti kosmicheskikh luchey (Intensity variations of cosmic rays). Moskva, 1960. (ITS: Trudy. Seriya fizicheskaya, no. 3) 166.

6. First to appear in worldwide use. Ekonomicheskaya gazeta, 4 May 1961, 2.

7. Television camera on the end of a drill. Yunnyy tekhnik, no. 2, Feb 1961, 21.